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Final Report
Fire Behavior Information System (FBIIS)

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GRADIENT MODELING, INC.

Stephen R. Kessell
President

RM78

Reply to:

A Montana non-profit corporation devoted to ecological research and management application.

FINAL REPORT

FIRE BEHAVIOR INFORMATION INTEGRATION SYSTEM (FBIIS)

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October 15, 1976 - March 1, 1977

Submitted by: _____ date 3/7/77
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Accepted by: _____ date _____
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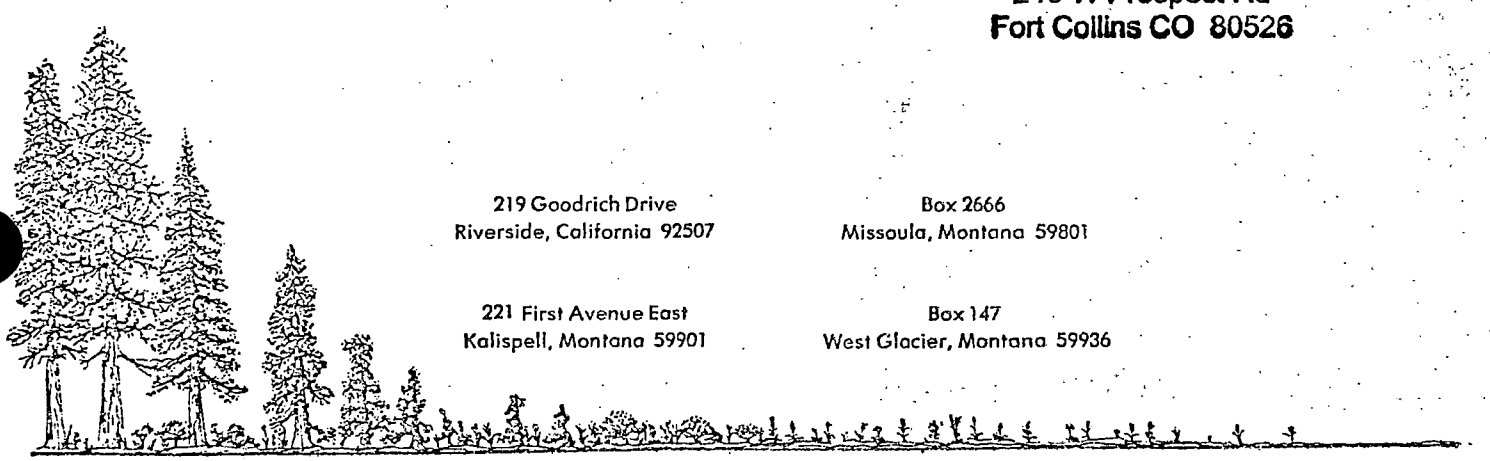

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INTRODUCTION:

A prototype Fire Behavior Information Integration System (FBIIS) was developed for a 140 square kilometer subset of the FIRESCOPE area to meet the following criteria:

1) provide a data base package that retrieves and displays site, vegetation, fuel, cultural and hydrological information using currently available data;

2) provide a data base system that can be later refined to consider the environmental and cultural impacts on vegetative community structure, composition and dynamics;

3) provide data retrieval, integration and display in the form of both local site descriptions and summaries for larger areas;

4) provide an analytical and data framework for comparing the effects of different levels of site resolution on data integrity, accuracy and costs; and

5) evaluate the potential for using ERTS-LANDSAT remote digital data as the primary site-specific data base.

STRUCTURE OF THE FBIIS:

The FBIIS provides data retrieval, integration and display capabilities by linking three major components:

1) a site-specific inventory coded from aerial photos (U-2 false-color infrared), topographic maps and fire history records;

2) matrix models of fuel loadings and packing ratios; and

3) a software package linking these components to provide data retrieval, integration and display.

Remote Site Inventory. The Remote Site Inventory provides a methodology and digital site-specific data base for storing key landform, vegetation, cultural and hydrological data recorded from aerial photos, topographic maps and fire records. It also provides the site parameters required by the fuel models to provide fuel data inference capability. The basic system codes a separate record for each hectare (square with sides = 100 m), blocks these records within square kilometer areas (100 ha) indexed by Universal Transverse Mercator (UTM) coordinates, and provides within-site resolution down to 0.25 ha. The record format is shown in Table 1.

The 140 sq km prototype area is located primarily within the Angeles National Forest northeast of Glendora, as shown in Figure 1. It includes the 80 sq km rectangle bounded by UTM 3779 North, 420 East - 3779 North, 436 East - 3784 North, 420 East - 3784 North, 436 East, and the 60 sq km rectangle bounded by UTM 3784 North, 430 East - 3784 North, 436 East - 3794 North, 430 East - 3794 North, 436 East. Coding procedures are detailed below.

Prior to coding the records for each sq km, the square grid (from the 7½' topographic maps) is transferred to the 1:100,000 scale aerial photo. Several checkpoints are required due to photo distortion (primarily due to elevation changes and edge effect). Upon completion, a 5 x 5 grid (each cell = 200 m x 200 m,

Table 1. Remote Site Inventory Record Format.

First record for square kilometer ----------

column	information (FORTRAN format)
1-4	UTM North of Sq Km (I4)
5-7	UTM East of Sq Km (I3)
8-11	Year coded (I4)
	Hydrological data:
12-13	% of Sq Km covered by standing water (100 % is coded as 99; less than 1% but greater than 0 is coded as -1) (I2)
14	Highest order stream in NE 25% of Sq Km (I1)
15	Highest order stream in SE 25% of Sq Km (I1)
16	Highest order stream in SW 25% of Sq Km (I1)
17	Highest order stream in NW 25% of Sq Km (I1)
	Cultural data:
18-21	Total number of buildings in Sq Km (I4)
22	Highest order road in NE 25% of Sq Km (I1)(code col 31 below)
23	Highest order road in SE 25% of Sq Km (I1) "
24	Highest order road in SW 25% of Sq Km (I1) "
25	Highest order road in NW 25% of Sq Km (I1) "
26-27	Total number of small water sources (I2)
28	Average slope steepness for Sq Km (I1), where 0 = 0 % 1 = 0 - 15 % 2 = 15 - 30 % 3 = 30 - 45 % 4 = 45 - 60 % 5 = 60 - 75 % 6 = 75 - 100 % 7 = 100 - 125 % 8 = over 125 %

Next 100 records (1 record per 1 ha block) ----------

	Site data:
1-2	Preprinted hectare UTM North & East coord. (I2)
3-7	Elevation in feet (nearest 20 feet) (I5)
8-10	Stand age (years) (-1 = mature) (I3)
11	Intensity of last fire (I1), where 0 = destroyed over 75 % of top stratum 1 = destroyed over 25 % but less than 75 % of top stratum 2 = understory fire, top stratum intact
12-13	Topographic type(s) (2I1) (Note: if only one type is coded, it is major type, and no secondary type covered 25 % of ha.) col 12 = predominant topography col 13 = secondary topography, where 1 = flat 2 = canyon 3 = draw 4 = slope 5 = ridge or peak 6 & 7 are not used 8 = urban (developed) 9 = lake, pond or reservoir

Table 1 continued

column	information (FORTRAN format)
14	Aspect (I1), where 1 = north 2 = northeast 3 = east 4 = southeast 5 = south 6 = southwest 7 = west 8 = northwest
15-18	Cover type(s) (2I2) (Note: This is a hierarchy system, where the first digit defines the type, and the second digit refines that basic type description. Also note: When only one topographic type is recorded, one or two cover types may be recorded. If two topographic types are recorded, then two cover types will be recorded -- one corresponding to each topographic type -- even if both topographic types have the same cover type). col 15-16 = predominant cover type col 17-18 = secondary cover type (covers at least 25 % of ha), where 10 = Barren 20 = Grass 31 = Mixed soft chaparral 40 = Hard chaparral 41 = Mixed hard chaparral 42 = Scrub oak - oak woodland - chaparral 43 = Desert chaparral, non-contiguous 32 = Chamise 50 = Forest enclaves and emergents -- coded only as a secondary type when hard chaparral series is predominant type 51 = Oak enclaves 52 = Douglas-fir enclaves 53 = Pine emergents 60 = Forests 61 = Broadleaf forest, not differentiated 62 = Oak woodland 63 = Pinyon - Juniper, continuous 64 = Open Pinyon - Juniper, not continuous 65 = Riverine complex 66 = Coniferous forest, not differentiated 67 = Pine forest 68 = Mixed pine - fir forest 69 = Subalpine forest 70 = Desert 71 = Open desert 72 = Joshua Tree woodland 73 = Sage

Table 1 continued

column	information (FORTRAN format)
19	Land cultivated ? (I1) 0 = No 1 = Yes
	Hydrological data:
20	Pond, lake or reservoir present in ha ? (I1) 0 = No 1 = Yes
21	Small water source (swim pool, tank, etc.) present ? (I1) 0 = No 1 = Yes
22	Order of largest stream in ha (I1)
	Cultural data:
23-24	Total number of buildings in ha (not differentiated, but includes sum of col. 25-30 below) (I2)
25-26	Total number of residential buildings in ha (I2)
27-28	Total number of commercial buildings in ha (I2)
29-30	Total number of deserted buildings in ha (I2)
31	Highest order road in ha (I1), where: 0 = none 1 = trail 2 = jeep road 3 = Dirt road 4 = paved, 2 lanes 5 = paved, more than 2 lanes
32	Artificial firebreak in ha ? (I1) 0 = No 1 = Yes
33-34	If col 32 = 1, Approx width of firebreak (m) (I2)
35	If col 32 = 1, Orientation of firebreak (I1), where 1 = north-south 2 = northeast-southwest 3 = east-west 4 = southeast - northwest

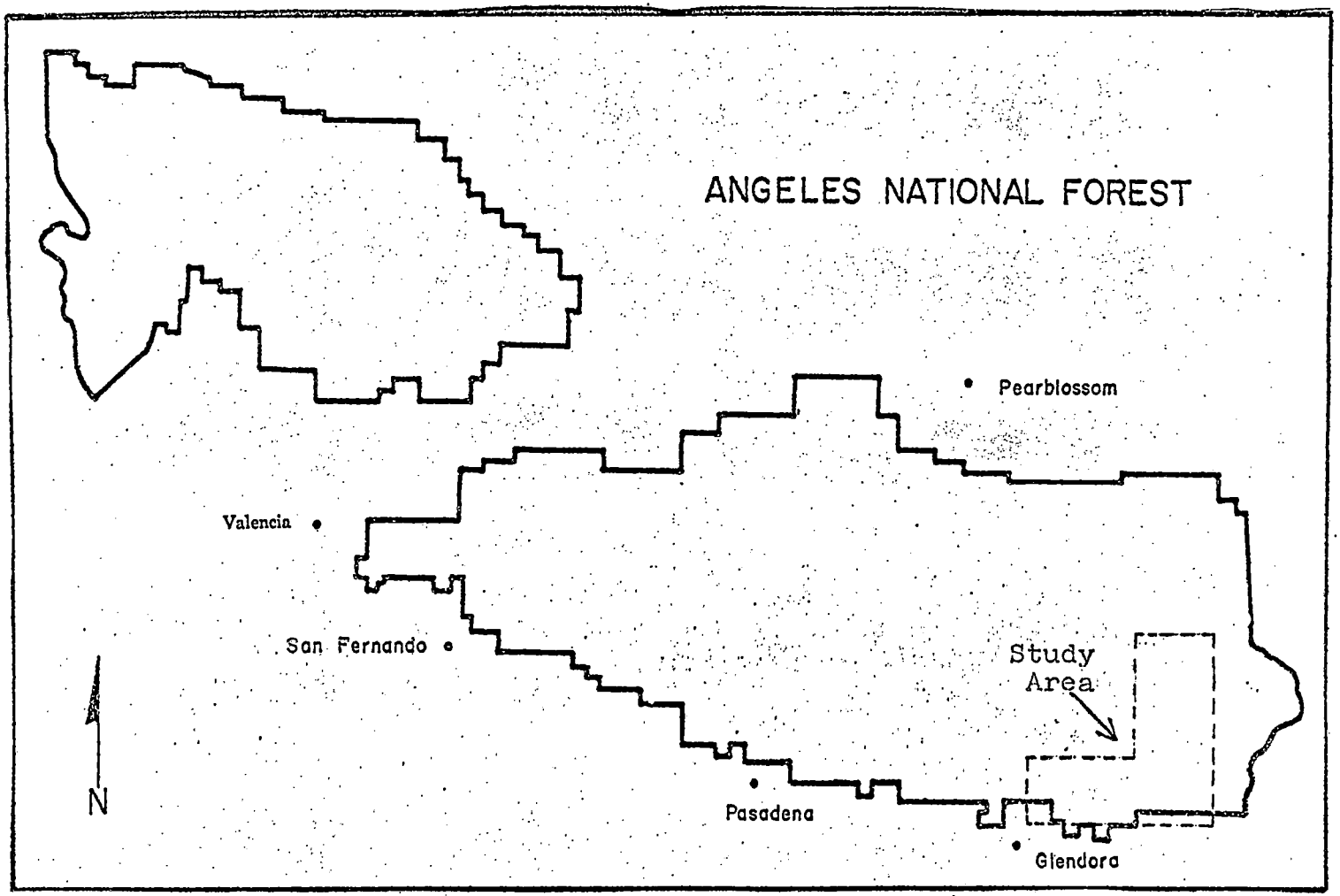


Figure 1. Location of the prototype area in the Angeles N. F.

= 4 ha) is then transferred within the sq km grid. Fire perimeters are then transferred to the photo. Interpretation is now conducted using stereo pairs of U-2 photos under 5 - 20 X magnification. Individual hectares are coded first, and then the (first record) summary is completed (see Table 1).

Following the coding sequence shown in Table 1, hectare UTM coordinates (col 1-2) are preprinted. Elevation (col 3-7) is read from the 7½' topographic map to the nearest 20 feet (6.10 m). Stand age (col 8-10) is computed from the fire history transfer (usually an age over 50 years is considered mature, code = -1). Default fire intensity (col 11) is high intensity (code = 0). Fires which obviously did not destroy the majority of the top stratum are coded appropriately.

Topographic type(s) (col 12-13) are coded for the most common topography, and if a second topographic type occupies at least 25 % of the hectare, for the secondary type as well (col 13). "Flat" is an area of slope less than 5 %. "Canyon" is a V-shaped depression, usually steep-sided, which carries running water after moderate precipitation. "Draw" is a U-shaped depression, with more gentle sides than a canyon. "Slope" is an area with steepness over 5 % which drains in a single predominant direction. "Ridge - Peak" is a narrow area which drains in two (ridge) or more (peak) major directions. "Urban (developed)" is an area with development in the form of buildings and roads. "Lake, pond or reservoir" is an area which contains standing water except during drought or let-down conditions. Aspect (col 14) is coded to the nearest of eight compass points (true, not magnetic).

Cover type(s) (col 15-18), like topography, are coded for the most common vegetative cover, and if a second vegetative cover occupies at least 25 % of the ha, for that secondary type as well (col 17-18). In addition, if two topographic types are recorded for the ha, then two cover types will also be recorded, corresponding to each topographic type in sequence (even if both topographic types exhibit the same vegetative cover). Cover types were chosen based on two criteria:

1) they must be distinguishable from the U-2 or similar moderate resolution (1:50,000 - 1:150,000) photos or imagery records; and

2) the type distinctions must provide some meaningful insight into the associated vegetation composition and/or flammable fuel characteristics. Types are distinguished as follows (sequence of Table 1):

10 Series (Barren): areas of rock or mineral soil, void of vegetation except for scattered grass or forbs, fuel discontinuitie to prevent fire spread (U-2 type B).

20 Series (Grass): areas of continuous or nearly continuous grass cover, shrub cover low or absent. Scattered trees will be recorded as a secondary type from the 50's or 60's series if crown cover reaches 25 % (U-2 type G).

30 Series (Soft chaparral): Type 31, Mixed Soft Chaparral, areas of predominantly non-woody shaparral species (U-2 types C_s and C_{af}).

40 Series (Hard chaparral): Type 41, Mixed Hard Chaparral, areas of predominantly woody chaparral species not meeting the

criteria of Types 42, 43 or 32 (U-2 type C_H); Type 42, Scrub Oak - Oak Woodland and Chaparral, areas of soft or hard chaparral with oaks exhibiting cover of at least 25 % (U-2 types C_{so} and C_{WD}); Type 43, Desert Chaparral, not found in the study area (U-2 type C_D); Type 32, Chamise, areas which are predominantly chamise (U-2 type C_{af}).

50 Series (Forest enclaves and emergents), coded only as a secondary type where grass or hard chaparral is the predominant type: Type 51, Oak Enclave, areas of predominantly oak with little chaparral understory (U-2 type CF_{co}); Type 52, Douglas-fir Enclave, areas of predominantly Douglas-fir with little chaparral understory (U-2 type CF_{bs}); Type 53, Pine Emergents, areas of predominantly pine with a chaparral understory (U-2 types CE_{cp} and CE_{kb}).

60 Series (Forests): Type 61, Broadleaf Forest, areas of predominantly broadleaf trees which can not be differentiated into types 62 - 65; Type 62, Oak Woodland, areas of predominantly oaks growing in a woodland habitat (as opposed to type 42 or 51 habitats) (U-2 types C_{WD}, and DF); Type 63, Pinyon - Juniper, areas of predominantly Pinyon and Juniper (U-2 types PJ and PJ_D); Type 64, Non-continuous Pinyon - Juniper, areas of spotty or clumped Pinyon and Juniper, with sage or mixed understory (U-2 type PJ_O); Type 65, Riverine Complex, areas of predominantly riverine - riparian broadleaf species located on flats or canyons (U-2 type R); Type 66, Coniferous Forest, areas of predominantly coniferous trees which can not be differentiated into types 67 - 69;

Type 67, Pine Forest, U-2 type PF; Type 68, Mixed Pine - Fir Forests (U-2 type PF_m); Type 69, Subalpine Forests, U-2 type LP.

70 Series (Desert - not found in study area): Type 71, Open desert (U-2 type D); Type 72, Joshua Tree Woodland (U-2 type JS); Type 73, Sage (U-2 type GB).

Obvious cultivation of the site is recorded in col. 19 . Hydrological data are recorded in col. 20-22 . Presence of a pond, lake or reservoir is recorded in col. 20 . Presence of a small water source, such as a swimming pool or water tank, is recorded in col. 21 . The order of the largest stream is recorded in col. 22 (blank = temporary stream or no stream).

Cultural data are recorded in col. 23-31. Total number of buildings (col 23-24) is recorded from the photos (which are more recent than the maps). These are further differentiated by type (col 25-30) if possible. Col. 31 contains the code for most developed access to the ha.

Firebreaks (col 32-35) are recorded by presence of an artificial firebreak (col 32), approximate width of the firebreak in m (col 33-34) and orientation of the firebreak (col 35).

Square kilometer summary data (first record of data block -- see Table 1) include UTM coordinates (col 1-7), year coded (col 8-11), a summary of hydrological data (col 12-17), a summary of cultural data (col 18-25), total number of small water sources (col 26-27) and average slope steepness (average steepness of topographies coded as "slope" -- col 28).

Total coding time for this system, including records ha by ha, 0.25 ha resolution of topography and cover type, and sq km summary, (includes locating the materials, constructing the grids, transferring data to the photos, recording the data, and checking the results) averages about 4 man-hours per sq km. This is variable due to discontinuities in terrain, cover and cultural development. Total costs thus average $ 0.20 / ha (exclusive of keypunching, computer and software development).

Field checking of this data base was conducted by ground visits to approximately 250 1 ha stands (5 trips to the study area, = 15 man-days). The only errors detected was the failure to pick up oak enclaves (with 30 - 35 % cover) in 7 canyon habitats. These sites were thus coded as cover "41", when the correct code should have been "42" or "41-51".

The use of these site data for information retrieval and integration with fuel models is described below, while the effects of alternative resolution levels and different data sources are discussed in later sections.

Fuel Matrix Models. The fuel matrix models were devised to provide fuel loading (by fuel type and size classes) and packing ratios (by strata) inference capabilities using available ground truth fuels data and input parameters provided by the Remote Site Inventory described above.

Although four-index (four gradient) models are often required to describe coniferous forest fuels in Montana (Kessell 1976a, 1976b, 1977; Jeske and Bevins 1976), the availability of ground truth fuels data for the FIRESCOPE area did not permit such an ambitious attempt for the FBIIS. Instead, two indexes (or gradients) -- cover type and stand age --were used to construct a 5 x 11 matrix for each fuel type - size class loading and stratum packing ratio. The matrices are shown in Table 2.

Stand age is represented by an 11-element vector of 5 year increments, with all stands over 50 years old grouped as "mature" (last element). Cover types from the Remote Site Inventory are grouped into 5 major vegetation types as follows:

Grass (types 20, 70, 71, 72 and 73)

Soft chaparral (types 30 and 31)

Hard chaparral (types 40, 41, 42, 43 and 32)

Broadleaf forest (types 50, 51, 60, 61, 62, 63, 64 and 65)

Coniferous forest (types 52, 53, 66, 67, 68 and 69)

Chaparral fuel loads were determined from Rothermel and Philpot (1973), unpublished data and other sources provided by Tim Paysen, Riverside Fire Lab. Grass fuels were determined by modification of the NFRD "A" model (Deeming et al. 1972) to permit grass and forb build-up during the first 15 years after a burn (to a plateau loading of 6.0 tons/ha). Coniferous forest fuels were determined from extensive coniferous fuels data collected in Montana (Kessell 1976b, 1977; Jeske and Bevins 1976). Successional broadleaf forest fuels closely mimic hard chaparral fuels, while

Table 2. Matrix models for fuel loadings and packing ratios.

VEG COVER	STAND AGE (YEARS) 0- 5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	50+
0 - 1/8" Branchwood Loadings (tons/ha)											
Grass	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Soft chaparral	0.15	0.36	0.57	0.57	0.66	0.71	0.71	0.77	0.77	0.77	0.77
Hard chaparral	0.64	1.7	2.4	3.1	3.6	4.1	4.5	4.9	5.2	5.2	5.2
Broadleaf forest	0.6	1.6	2.2	3.0	3.5	4.0	4.3	4.5	4.5	4.0	0.13
Coniferous forest	0.12	0.12	0.15	0.20	0.25	0.25	0.25	0.25	0.25	0.25	0.25
1/8 - ¼" Branchwood Loadings (tons/ha)											
Grass	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Soft chaparral	0.44	1.07	1.7	1.7	2.0	2.1	2.1	2.3	2.3	2.3	2.3
Hard chaparral	2.0	5.3	7.7	9.7	11.4	12.8	14.2	15.4	16.2	16.2	16.2
Broadleaf forest	1.8	5.0	7.2	8.0	10.	10.	10.	10.	10.	10.	0.6
Coniferous forest	0.30	0.30	0.45	0.60	0.80	0.80	0.80	0.80	0.70	0.70	0.60
¼ - 1" Branchwood Loadings (tons/ha)											
Grass	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Soft chaparral	1.26	3.1	4.9	4.9	5.6	6.1	6.1	6.6	6.6	6.6	6.6
Hard chaparral	4.0	10.3	15.	19.	22.2	25.	27.7	30.1	31.7	31.7	31.7
Broadleaf forest	4.0	10.3	15.	19.	22.2	25.	27.7	30.1	31.7	31.7	31.7
Coniferous forest	2.8	2.8	2.2	1.6	1.2	1.2	1.2	1.3	1.4	1.5	1.7
1 - 3" Branchwood Loadings (tons/ha)											
Grass	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Soft chaparral	0.15	0.36	0.57	0.57	0.66	0.71	0.71	0.77	0.77	0.77	0.77
Hard chaparral	0.37	0.96	1.4	1.8	2.1	2.3	2.6	2.8	3.0	3.0	3.0
Broadleaf forest	0.37	0.96	1.4	1.8	2.1	2.3	2.6	2.8	3.0	3.0	3.0
Coniferous forest	6.0	6.0	5.0	4.2	3.4	3.4	3.4	3.8	4.2	4.8	6.0
Over 3" Branchwood Loadings (tons/ha)											
Grass	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Soft chaparral	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Hard chaparral	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Broadleaf forest	1.7	1.7	1.8	1.8	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Coniferous forest	28.	28.	30.	30.	32.5	32.5	32.5	34.	34.	35.	38.

Table 2 continued

VEG COVER	0- 5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	50+
Shrub foliage Loadings (tons/ha)											
Grass	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Soft chaparral	0.15	0.36	0.57	0.57	0.66	0.71	0.71	0.77	0.77	0.77	0.77
Hard chaparral	2.2	5.7	8.4	10.6	12.4	13.9	15.5	16.8	17.7	17.7	17.7
Broadleaf forest	2.2	5.7	8.4	10.6	12.4	13.9	15.5	16.8	17.7	17.7	0.8
Coniferous forest	1.1	1.1	0.95	0.85	0.75	0.75	0.65	0.55	0.50	0.45	0.35
Grass and forbs Loadings (tons/ha)											
Grass	1.5	2.0	4.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Soft chaparral	1.5	0.8	0.45	0.45	0.45	0.45	0.45	0.40	0.35	0.30	0.20
Hard chaparral	1.5	0.8	0.45	0.45	0.45	0.45	0.45	0.40	0.35	0.30	0.20
Broadleaf forest	0.48	0.48	0.45	0.45	0.45	0.45	0.45	0.40	0.35	0.30	0.20
Coniferous forest	0.48	0.48	0.45	0.45	0.45	0.45	0.45	0.40	0.35	0.30	0.20
Shrub Stratum Packing Ratio (dimensionless)											
Grass	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001
Soft chaparral	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002
Hard chaparral	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003
Broadleaf forest	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003
Coniferous forest	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
Grass and forbs Stratum Packing Ratio (dimensionless)											
Grass	.0017	.0017	.0017	.0017	.0017	.0017	.0017	.0017	.0017	.0017	.0017
Soft chaparral	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005
Hard chaparral	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005
Broadleaf forest	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005
Coniferous forest	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01

mature broadleaf forest fuels are based on Rothermel (1972).

It is recognized that weaknesses exist in this fuels data base. Rather than refine current state-of-the-art FIRESCOPE fuel models, the purpose of this work was to provide realistic models of fuels based on ground truth data which could subsequently be used to test the FBIIS, compare resolution levels and identify areas where further field work is desirable. (As discussed in the next section, the fuel models are external to the basic software package, and may easily be modified by the user without making changes in the source program).

Software Package. The remote site inventory and fuel models are linked by a FORTRAN IV source program operating on the (Riverside Fire Lab) HP-2000 facility to provide data retrieval, integration and display.

All required input data, including fuel models, dictionaries and site inventory for the 140 sq km study area, are included in a single 80-character record format magnetic tape file (MEMOREX 964383130). The source program (Program FBIIS, Version 11, 770228) is stored on disk as file "SGMI1", while the object module (ready for execution) is stored on disk as file "RGMI1". A back-up copy of the source program is stored as the first file on magnetic tape (PRIMUS AD12362125010). An extensively documented copy of the source program FBIIS is provided with the originals of this report.

The source program FBIIS is interactive. After setting dimensions and reading the fuel models and dictionaries, it

requests the user to specify the date and operation mode. The date is used to increment stand ages of any location whose site inventory was coded in a year prior to the current year. (Thus, specification that the date is now 1978 will add 2 years' age to all stands coded in 1976, with subsequent increases in fuel loadings).

If the Hectare Mode is selected, the user inputs options desired and the UTM coordinates for the sq km containing the desired hectares. Upon locating the correct site inventory records, the program requests user input of hectare coordinates, then displays the results for the options selected. This process continues with new hectares until the user specifies return to select another sq km or return to mode selection.

If Summary Mode is selected, the user inputs options desired and the UTM coordinates for all the square kilometers to be included in the summary. (There is a limit of 10 sq km on the HP-2000 System due to core limitations; this limit would be several hundred square kilometers on a large time-sharing system). As each sq km block of records is located and read, summary tallies are computed. The results are displayed after the last block of site records is processed. The program then returns to mode selection.

The program provides direct data retrieval, summarization and display for all options except fuel. When fuel is requested, the recomputed stand age (as noted above) and cover type are used as matrix indices to locate the correct fuel parameter for each loading and packing ratio. If two cover types are present for a

hectare, these values are computed for each cover type, and a weighted average is then computed and displayed based on the assumption that the predominant cover type occupies 70 % of the ha, and that the secondary cover type occupies 30 % of the ha.

In the computation of the fuel summary, this process is completed for each individual hectare within each sq km selected, and the results are used to derive a mean, sample deviation and confidence intervals (assuming a normal distribution) for each loading and packing ratio.

Finally, in the firebreak summary, "artificial" firebreaks are those coded as such in the site inventory. In addition, hectares which have a cover type(s) of "barren" only are flagged and displayed as "natural" firebreaks (see next section).

Operation of the program and interpretation of the output are described below.

PROGRAM OPERATION AND OUTPUT:

Operation. Prior to executing the program, it is necessary to get the HP-2000 system to a ready ("@") state by bringing up the system, entering ":DA,," and ":JO". Next, the master data tape for the FBIIS (MEMOREX 964383130) must be mounted and advanced to the beginning of the first file ("LOAD" button on tape unit).

With the load module ("RGMI1") residing on the disk, execution of the program requires the single command ":PR,RGMI1". Upon carriage return, the tape will rewind, the program will read

the fuel models and dictionaries, and then print a welcome message (see sample run in Appendix 1). From this point on, the user simply responds to program requests for options, specifications and inputs.

If the load module ("RGMI1") is not on the disk, it may be generated from the source program file ("SGMI1") as follows:

```
:CL
:JF,SGMI1
:PR,FTN4,2,4,99
:PR,LOADR,0,4
:ST,P
:RN,FBIIS,RGMI1
```

The load module is then executed by the command ":PR,RGMI1" as described above.

If the source program ("SGMI1") is not on the disk, it may be copied from the back-up tape (PRIMUS AD12362125010). To do this, mount this tape, advance it to the beginning of the first file ("LOAD" button), and then copy the first file to disk by ":ST,S,SGMI1,8". When the system asks "DONE?", respond "YES". Then compile, build the load module and execute as described above (but remember to remount the MEMOREX master data tape).

Output. Appendix 1 contains sample output from the FBIIS operating in both modes, beginning with the ":PR,RGMI1" execution command.

After printing the welcome message (page A-1), the program requires the date. Minimum input required is the last 2 digits of the year in the first two columns. If month and day are entered, they must be in the stated sequence, without blanks. Inappropriate dates will be rejected and must be reentered.

Next operation mode is selected (page A-1). Only the first characters "H", "S" and "B" are recognized -- others are rejected and must be reentered. For this example, Summary Mode was selected first.

The program then requests the desired options from the 6 choices (page A-1). User may also request all options by simply typing "A", as was done in the example. (Note that if vegetation, fuel and firebreaks only were desired, the correct response would be "VFB"). If none of the requested options are recognized, the program will request they be reentered.

Next, the program requests UTM coordinates of the sq km desired for summary (page A-1). Remember, maximum is ten sq km on the HP-2000 system. The 7-digit UTM coordinates are entered one sq km per line. After all are entered, "-1" is entered on a new line to designate completion of selection.

Program then rewinds the tape, searches until it locates the first sqkm, and then reads that block of records and tallies summary data. Next, it rewinds the tape, searches for the next block of records (next sq km), and continues this process until all records required are read and processed. (Note than any sequence of sq km -- contiguous or not -- may be entered). If a requested sq km is not on the tape, the user is alerted and is given the chance to abort or continue the run. If the run is aborted, the program returns to mode selection.

Summary output (page A-2) includes a listing of the area coordinates, a breakdown of elevation by 500 ft (152.4 m) classes,

a breakdown of topographic types into the major types, a breakdown of aspects into the 8 classes, and the average slope steepness (page A-3). For each breakdown, integers are used for hectares and decimal numbers for percentages. This completes output under the "Site-Terrain" option.

Vegetative cover (page A-3) output includes a breakdown into the major cover types (by hectares and %). Next, each major type is further refined into member subordinate cover types where such resolution was coded in the site inventory. Thus, on page A-3, hard chaparral, which covers 318.2 ha (79.5 %), is composed of both "mixed hard" and "oak + hard". The percentages of these two subtypes sum to 100 %, while the total number of hectares sum to the total cover by hard chaparral (318.2 ha). This process is repeated for the other major cover types. The last output under the "Vegetation" option is a breakdown of stand ages (page A-4).

Next, fuel loadings (for 7 categories and size classes) and packing ratios (for each stratum) are displayed (page A-4). Note that the 5 size classes of branchwood correspond to time-lag classes of 5 min, 1 hr, 10 hr, 100 hr and 1000 hr, respectively. Shrub foliage and grass & forbs are dry weight for both living and dead foliage. "Means" are the arithmetic average of the individual hectare weighted average loadings. "Sample deviation" is the computed standard deviation calculated for each sample set. The 65 % and 95 % confidence intervals are the limits that will include 65 % and 95 %, respectively, of the individual hectares if the fuels are normally distributed (means $\pm$ 0.915 and 1.96 standard deviations, respectively). "Barren" hectares contribute zero fuel

loadings to the mean, sample deviation and confidence intervals, but do not affect packing ratios (packing ratio is undefined for zero fuel).

Cultural features (page A-4) include a summary, sq km by sq km, for the total number of buildings and the highest order aceess for each quarter.

Firebreaks (page A-5) denote the location of each firebreak, first by sq km UTM coordinates, then by hectare UTM coordinates. As noted earlier, artificial (A) firebreaks were coded on the site inventory, while natural (N) firebreaks are hectares with "barren" cover.

Hydrological features (page A-6) include a summary, sq km by sq km, of the total percent cover by water, the total number of small water sources, and the highest order stream for each quarter.

This ends Summary Mode output, and the program returns to mode selection. For the next example, Hectare Mode was requested (page A-6) with all options (page A-7). Next, hectares from the sq km "3779432" were requested.

Once the block of data is located and read, the program requests 2-digit hectare coordinates (page A-7). For the first example, hectare "01" was chosen. The analysis follows (pages A-7 and A-8).

Three more hectares were then selected (pages A-8 to A-10) for analysis. Upon completion, the user entered "-1" and may now choose another sq km for Hectare Mode analysis. If no other sq km is required, entering "-1" again returns to mode selection (page A-10)

Since all required processing with the FBIIS was completed, user typed "BYE" (page A-11) and program terminates.

EFFECTS OF VARIABLE SITE INVENTORY RESOLUTION:

Procedures. Once the basic FBIIS was made operational as described above, it was desirable to test the effects of various levels of site inventory resolution on system resolution, inference and costs. Three alternative resolution levels were chosen: 4 ha (squares with sides = 200 m), 11.1 ha (squares with sides = 333.3 m) and 100 ha (1 sq km) (squares with sides = 1,000 m). Emphasis was placed on the effects on vegetative cover and fuel outputs and costs.

To test the 4 ha and 11.1 ha systems, a representative 6 sq km portion of the study area was selected and re-coded for each of these resolution levels. This included a 4 sq km area in Marshall Canyon (UTM 3779 - 3781 N, 431 - 433 E) and a 2 sq km area in Coldwater Canyon (UTM 3791 - 3793 N, 435 - 436 E). Except for the basic grid size, coding procedures were identical to those used for the basic 1 ha FBIIS described above. (Thus, secondary topographic and vegetative cover types were coded if they occupied at least 25 % of the new block size).

The source program was rewritten to permit summary mode operation at these two new resolution levels, renamed "SGMI2" and "SGMI3", for the 4 and 11.1 ha systems, respectively, and stored as the second and third files, respectively, on the PRIMUS tape. The fuel models were unchanged.

Initially, the 100 ha system was tested on this same 6 sq km area, but the results were sufficiently promising that the 100 ha system was extended to the 75 sq km area bounded by UTM 3779 N, 430 E - 3779 N, 435 E - 3795 N, 430 E - 3795 N, 435 E. Rather than rewrite the FBIIS source program to handle single records for each sq km, it was simpler to manually retrieve fuel loadings from the fuel models.

For each resolution level and area described above, statistical summaries were prepared sq km by sq km for vegetation and fuel output (75 sq km @ 1 ha level, 6 sq km @ 4 ha level, 6 sq km @ 11.1 ha level, and 75 sq km @ 100 ha level).

Results. The results must be viewed at two levels:

1) how well the resolution level provides a description of individual sites of small area; and

2) how well the resolution levels provide inference or summary information over a large area (defined as one or more sq km).

This dual view of resolution is required as it is possible to produce a system which provides reasonably good large area summaries (by "averaging out" individual site errors -- ie, the fuel models of the NFDR) but poor descriptions for any given point on the landscape.

The degredation of summary data for individual square kilometers at the 4, 11.1 and 100 ha levels depended greatly on the uniformity of vegetative cover, stand ages and thus fuels within each sq km. Figures 2 through 5 show the extremes of the effects within the 6 sq km area described above.

FIGURES 2 - 5

Figure 2. Comparison of fuel data inference for the Sq Km 3780 N, 431 E, for the four resolution levels. Means are plotted for each resolution level (including the single deterministic prediction at the 100 ha level); the bars represent 1 and 2 standard deviations.

Figure 3. Comparison of vegetative cover data retrieved for the Sq Km 3780 N, 431 E, for the four resolution levels.

Figure 4. Same as Figure 2, except for the Sq Km 3791 N, 435 E.

Figure 5. Same as Figure 3, except for the Sq Km 3791 N, 435 E.

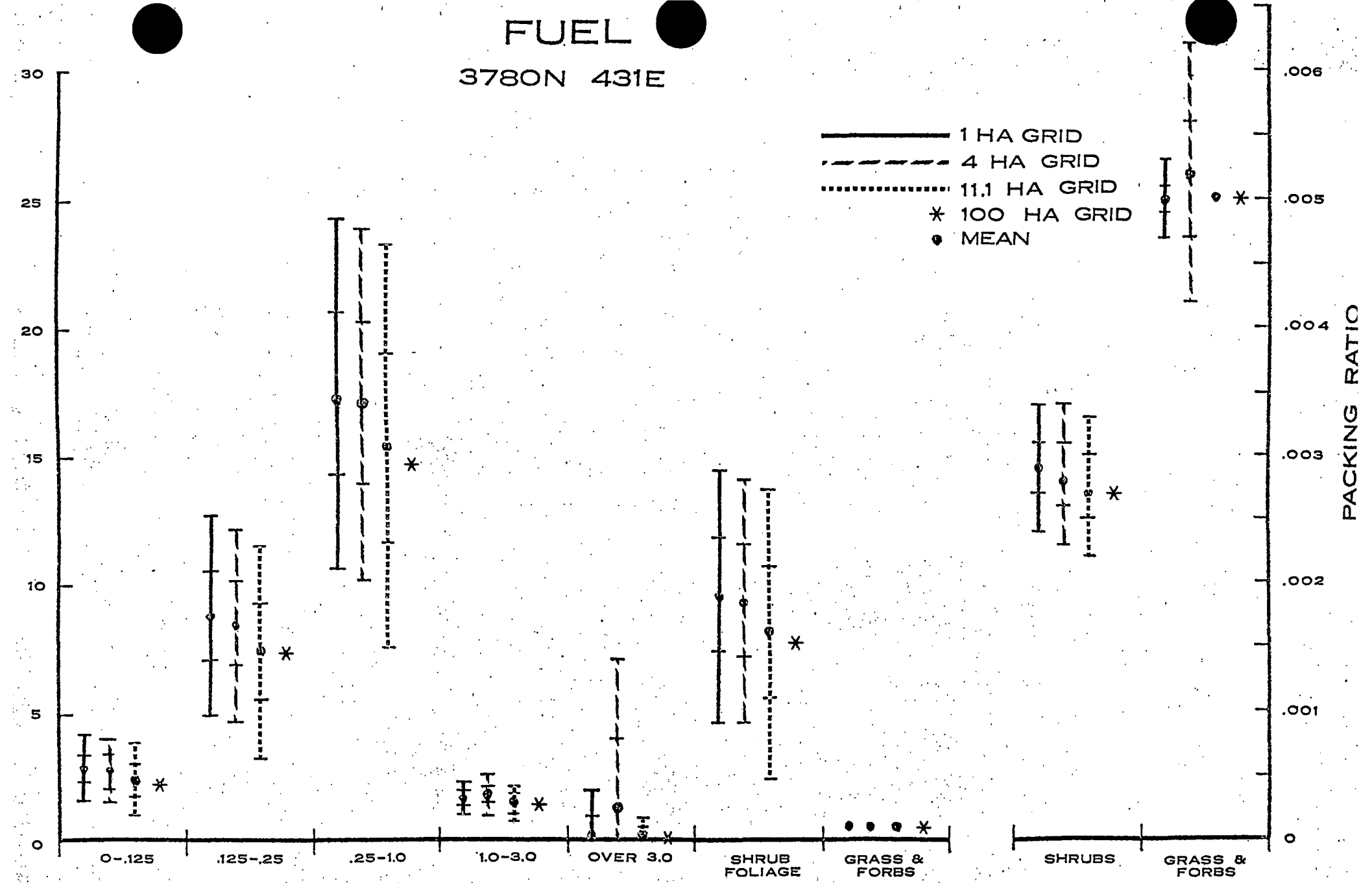

FUEL
3780N 431E
1 HA GRID
4 HA GRID
11.1 HA GRID
100 HA GRID
MEAN
30
25
20
15
10
5
0
.006
.005
.004
.003
.002
.001
0
PACKING RATIO
0-.125
.125-.25
.25-1.0
1.0-3.0
OVER 3.0
SHRUB FOLIAGE
GRASS & FORBS
SHRUBS
GRASS & FORBS
BRANCHWOOD (IN.)

FIGURE 2

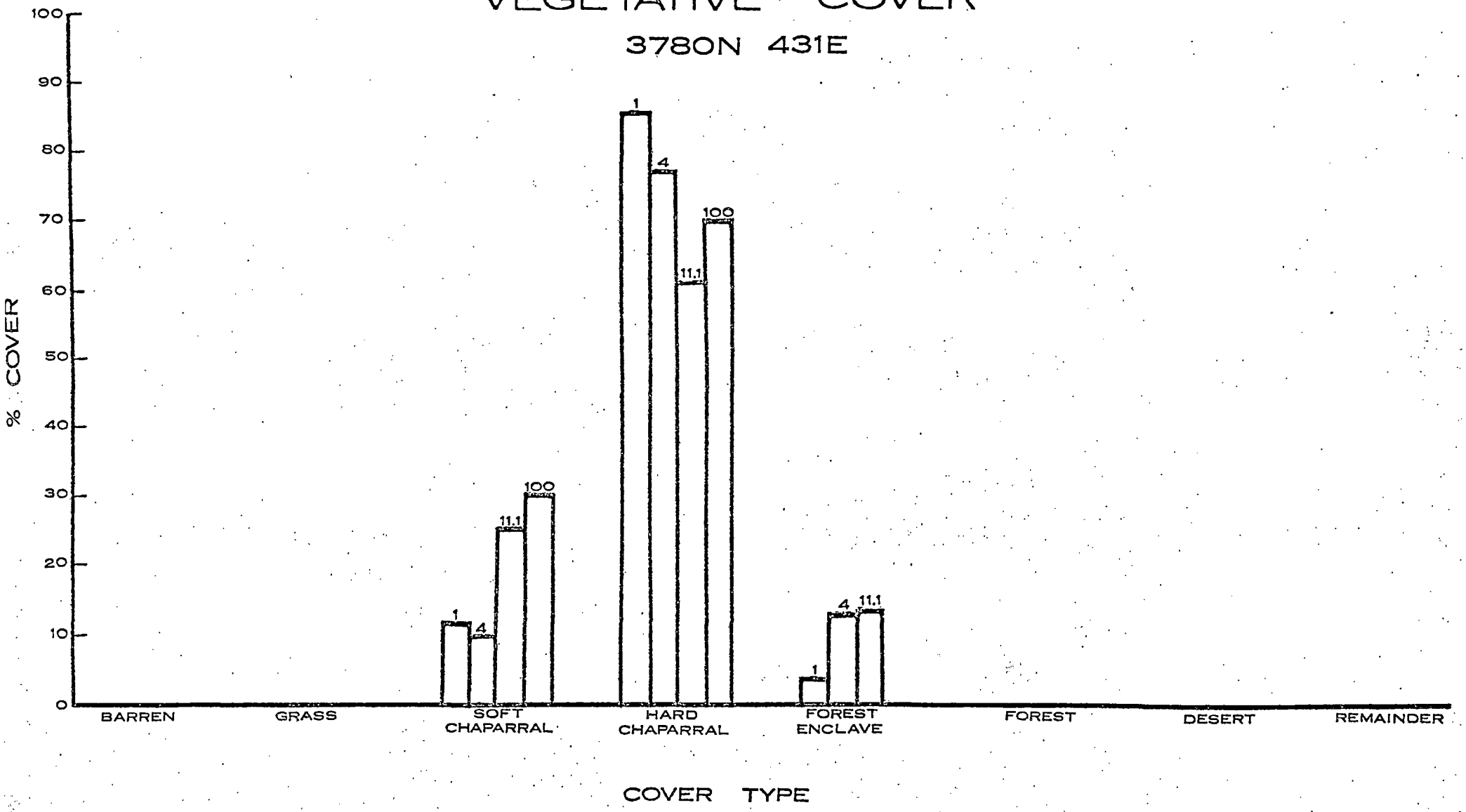

VEGETATIVE COVER
3780N 431E
% COVER
100
90
80
70
60
50
40
30
20
10
0
1
4
11.1
100
1
4
11.1
100
1
4
11.1
BARREN
GRASS
SOFT CHAPARRAL
HARD CHAPARRAL
FOREST ENCLAVE
FOREST
DESERT
REMAINDER
COVER TYPE

FIGURE 3

FUEL

3791N 435E

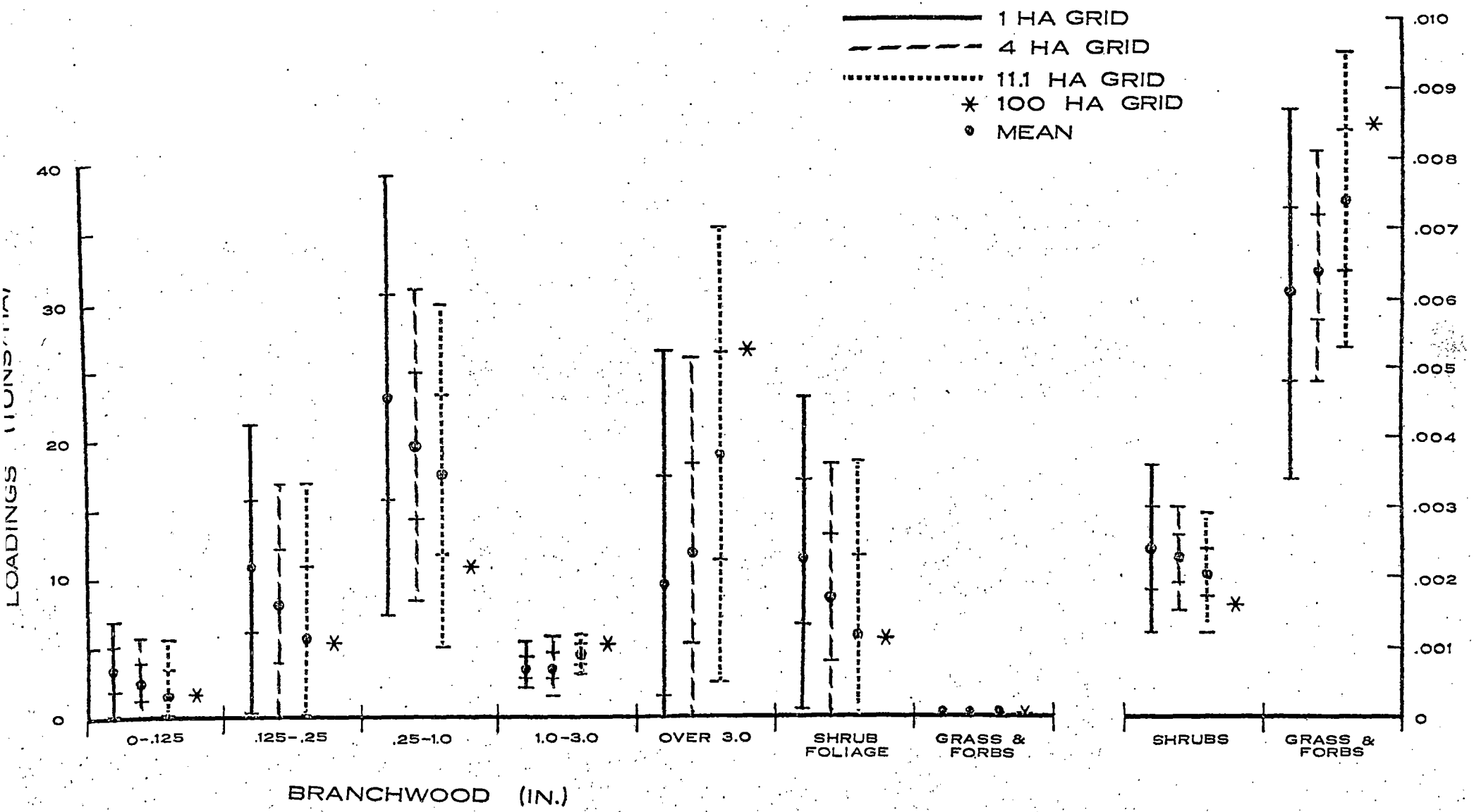
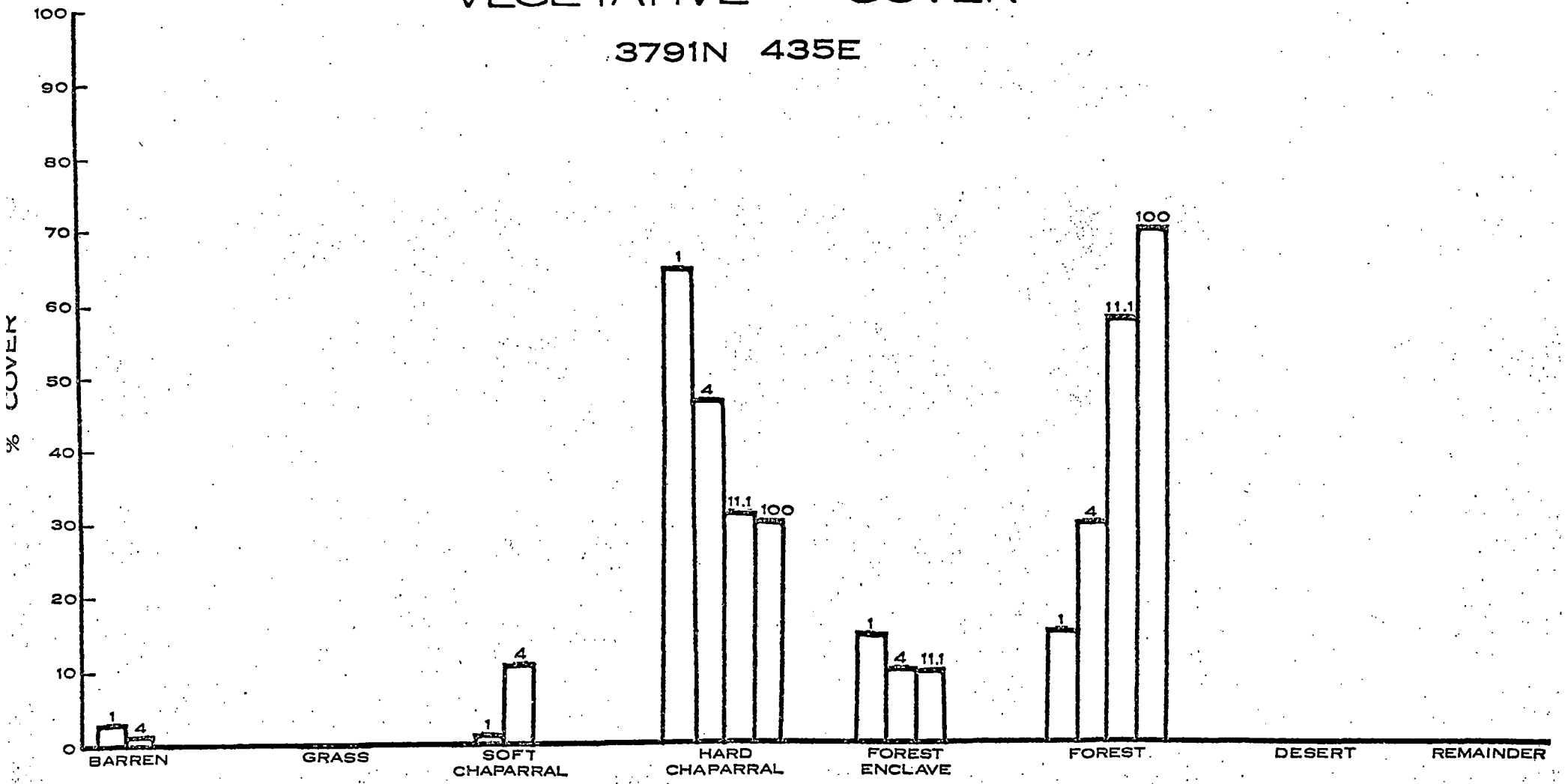


FIGURE 4

VEGETATIVE COVER

3791N 435E



COVER TYPE

FIGURE 5

The best results were obtained in sq km 3780 N, 431 E (Marshall Canyon), as shown in Figures 2 and 3. This area is predominantly mixed hard chaparral, with lesser soft chaparral and oak. The entire sq km burned in 1960. Figure 3 plots, for each fuel loading and packing ratio, the mean and error bars (1 and 2 standard deviations, respectively) for the 1, 4 and 11.1 ha systems, and the single (deterministic) prediction from the 100 ha system. Note that for all fuel parameters (except over 3.0" branchwood and grass & forbs packing ratio), the 4 ha system provides results almost identical to those provided by the 1 ha FBIIS. Larger errors are incurred with the 11.1 ha system, but still virtually all fuel parameters are within 1 SD of the 1 ha mean predictions. Even the 100 ha system does a fair job of predicting the fuel parameters most important to fire spread (fine branchwoods, shrub foliage and shrub packing ratio).

Figure 3 compares vegetative cover data retrieved for this same sq km. Again, there is little information loss with the 4 ha system, and even the 11.1 and 100 ha systems preserve the essential information that the area is predominantly hard chaparral with lesser soft chaparral and (oak) forest enclaves.

At the other extreme, Figures 4 and 5 show the results obtained in sq km 4791 N, 435 E (Coldwater Canyon), a higher elevation (1600 m) area which includes a more diverse cover mosaic (hard chaparral, forests, forest enclaves, barren and soft chaparral, in order of importance) which last burned in 1919. Here (Figure 4),

even the fine fuels predicted by the 4 ha system average about 0.6 standard deviations from the 1 ha FBIIS means, while considerably greater degredation is observed at the lower resolution levels. Retrieval of vegetative cover data (Figure 5) shows that forest is artificially increased, which the other cover types decrease, with cruder resolution levels.

This variability in response of the systems to different resolution levels presents the questions: How much resolution is required ? How much error or data loss is acceptable ? These must really be answered by management, not the researcher, but some points should be kept in mind:

What questions will be addressed by the system's data base and predictions, and what resolution is required to adequately answer each question ?

How do fuel errors translate as fire behavior estimate errors given an area's weather profile, terrain and control problems?

Is knowledge of a local mosaic pattern necessary, or is a generalized summary (such as provided in Figures 2 - 5) adequate ?

If localized information is required, must it be site-specific, or is it sufficient to know that minor cover or fuel types occur within the area without pinpointing them ?

In the above attempt to provide profiles of the effects of the four resolution levels tested, we were surprised by how well the very crude 100 ha system performed in areas of uniform

vegetative cover. Thus we expanded the 100 ha system test area to 75 sq km, and summarized the effects on fuel data integrity. The results appear in Table 3.

Comparison was made between:

A) The 100 ha system and the original 1 ha FBIIS; and

B) The assumption that the entire area is chaparral (but with known stand age) and the 1 ha FBIIS (to see if the 100 ha system offered real improvement over the latter assumption).

The results show that for the fine branchwood and shrub foliage fuels which spread a fire, the average errors of the 100 ha system are within 0.6 standard deviations of the 1 ha system's predictions. The 100 ha system does less well for larger fuels. However, the 100 ha system gives only half the fuel prediction error incurred by assuming that the world is chaparral, even through the same stand age resolution is used by both methods.

The results suggest that even the crude 100 ha system offers considerable improvement and refinement over existing data bases and inference methods, and could well provide a minimum baseline resolution level for future work.

Costs. As noted in the Progress Report, the relationship between resolution level and inventory costs is approximately inverse square-root -- that is, reducing the resolution level by a factor of 4 (1 ha to 4 ha) reduces the cost by a factor of two. This is due to fixed activities which change little with cruder resolution levels (locating materials, transferring grids and fire history overlays, and field checking results). Comparative costs of the four resolution levels tested are shown in Table 4, and offer

FUEL INFERENCE ERROR

LOADINGS --	A 100 HA GRID FBIIS *		B ASSUME CHAPARRAL *	
	tons/ha	error/SD ratio	tons/ha	error/SD ratio
BRANCHWOOD				
0 - 1/8"	0.48	0.59	0.89	1.09
1/8 - ¼"	1.49	0.61	2.80	1.15
¼ - 1"	2.58	0.55	5.00	1.07
1 - 3"	0.71	0.82	0.47	0.54
over 3"	3.89	1.61	4.58	1.90
Shrub Foliage	1.76	0.59	3.18	1.07
Grass & Forbs	0.30	0.82	0.35	0.95
PACKING RATIOS --				
Shrub stratum	.0007	0.82	.0005	0.60
Grass & forb stratum	.0008	0.93	.0006	0.70

*Sample size (N) = 7,500 ha

Table 3. Comparison of fuel errors when fuel is computed for 100 ha block resolution FBIIS (A) and the assumption that all land areas exhibit chaparral cover (B). "Errors" are deviations from fuel computed by the 1 ha FBIIS coded for the same area, and are expressed both as the average error, and as a ratio to the 1 ha FBIIS fuel standard deviations. Note that for the fine fuels which spread a fire (small branchwood and shrub foliage), even the crude 100 ha FBIIS reduces by half the error incurred when one assumes all cover is chaparral.

Table 4. FBIIS Remote Site Inventory Costs as a function of Site Inventory Block Size.

BLOCK SIZE	SMALLEST TOPOG. & COVER CODED	# RECORDS PER SQ KM	COSTS* PER HA	COSTS* PER 7½' topog sheet
1 ha	0.25 ha	101	$ 0.20	$ 3,000.
4 ha	1.0 ha	26	0.10	1,500.
11.1 ha	2.8 ha	10	0.06	900.
100 ha	25.0 ha	1	0.02	300.

*costs exclusive of keypunching, computer, additional programming or overhead.

an order of magnitude range in costs. This obviously must be considered in evaluation of the "effectiveness" of any resolution level.

Relationship Between Site Resolution and Fuel Models. The reader must realize that the above results of various resolution levels reflect an interplay between the site resolution units and the determinants of the fuel inference models.

The current FBIIS, as noted above, generates or infers fuels from two site indexes -- vegetative cover and stand age. Also as noted earlier, other site parameters (such as elevation and aspect) undoubtedly affect fuel loadings, but were not included in the FBIIS due to inadequate field data. A more sophisticated future version of the FBIIS which included these additional fuel determinants might well reveal greater information loss at the lower resolution levels. (For an alternative example, if the current system used only stand age, and not vegetative cover, to derive fuels, there would be virtually no information degredation for fuels at the cruder levels, as the stand age mosaic is much more constant that the vegetative cover mosaic). Remember, the current FBIIS uses two site indexes to derive fuels (cover and age), while the different resolution levels tested above varied only one index (cover).

Mapping Alternatives. Concurrently with the above testing of the different resolution levels, we conducted tests of the feasibility, costs and data integrity of graphic display (mapping)

as an alternative to digitization of the site inventory data for the FBIIS. This was conducted for the 6 sq km area noted above.

The resulting maps were useful primarily to visually display the information loss and mosaic level at the 1, 4 and 11.1 ha resolution levels. Examples for Marshall and Coldwater Canyons are shown in Figures 6 and 7. Careful observation of these vegetative cover overlays will reveal the kinds and areas of information loss, and resulting artificial simplification of the natural mosaic, at each resolution level.

As an alternative to digitization, however, the prospects look grim, as for each resolution level, the time required to draw legible overlay maps exceeded the time required to code the digital inventory for the FBIIS. Preparation of "clean copy" maps (such as Figures 6 and 7) took conisderably longer. This, combined with the lack of any automation capabilities when maps are used as the data base, suggests that mapping simply does not offer a practical alternative to the FBIIS.

If maps of vegetative cover are desirable, it would be simpler, cheaper and more effective to have computer print or plot maps generated from the digital remote site inventory.

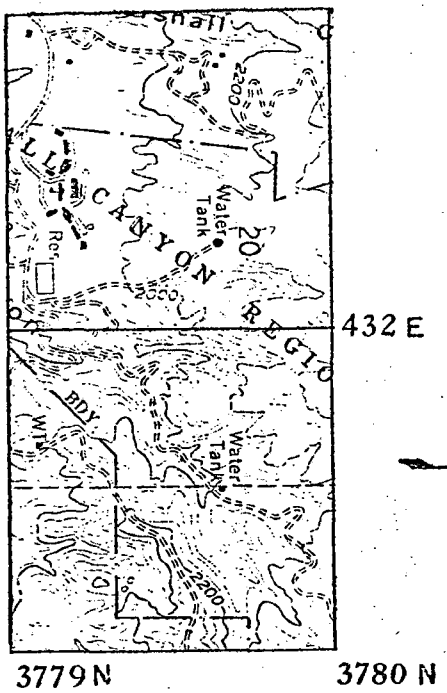
EVALUATION OF ERTS-LANDSAT AS A SITE INVENTORY DATA BASE

Due to the availability of a broad vegetative cover data base for the FIRESCOPE area from ERTS-LANDSAT imagery, it was

Figures 6 and 7. Vegetative cover overlay maps for two sq km areas in Marshall and Coldwater Canyons, respectively, show the information loss and artificial simplification of the natural vegetation mosaic at the 1, 4 and 11.1 ha resolution levels. Secondary cover types are mapped if the cover at least 25 % of the basic grid unit.

REMOTE SITE INVENTORY

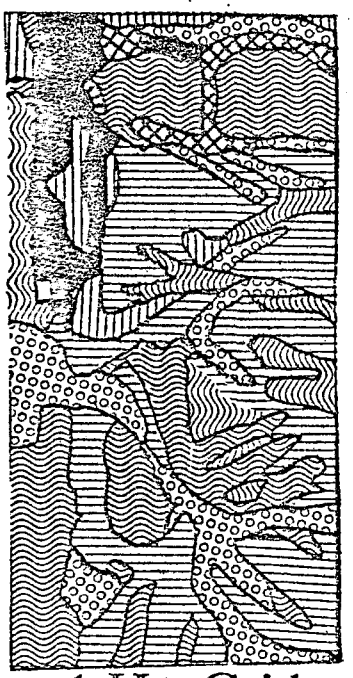
MARSHALL CANYON



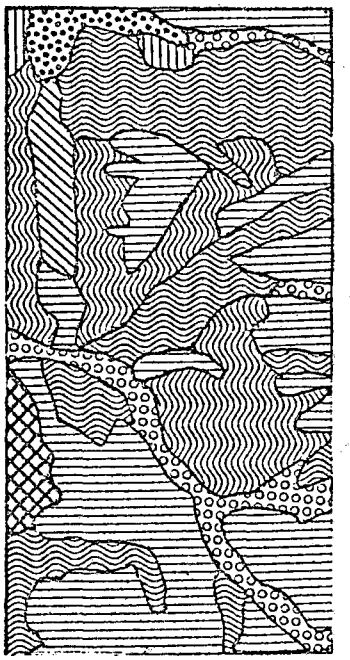
Scale

.5 0 1 Km.

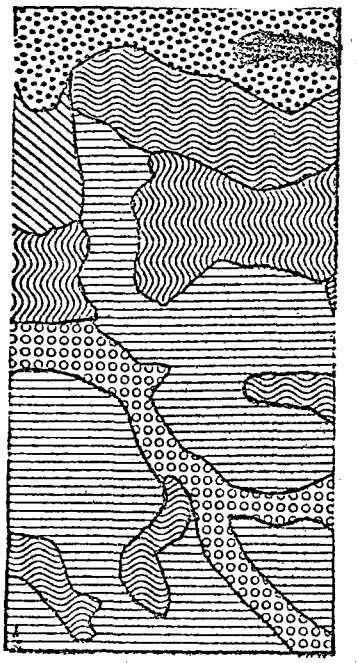
Base Map: U.S.G.S. 7½′ Quad



1 Ha. Grid



4 Ha Grid



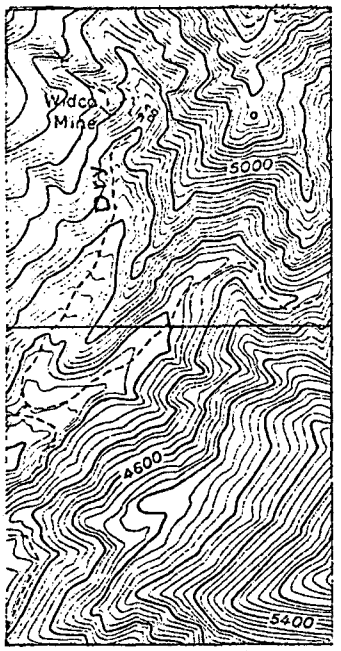
11.1 Ha Grid

COVER TYPES

- Barren
- Grass
- chaparral
- Mixed Soft
- Mixed Hard
- Scrub Oak
- Mixed Oak Woodland
- Mixed Pine Woodland
- forest
- Mixed Deciduous
- Mixed Coniferous
- Oak

REMOTE SITE INVENTORY

COLDWATER CANYON



3792 N

3791 N

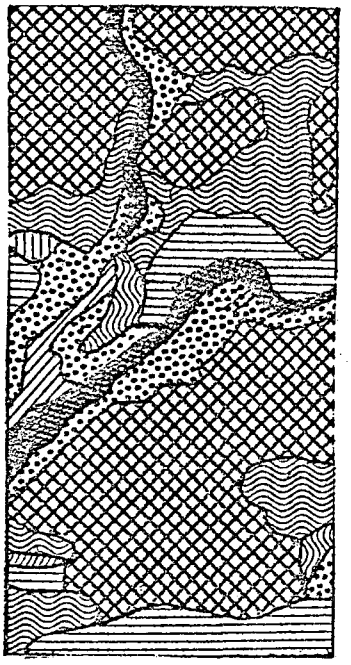
435 E

Scale

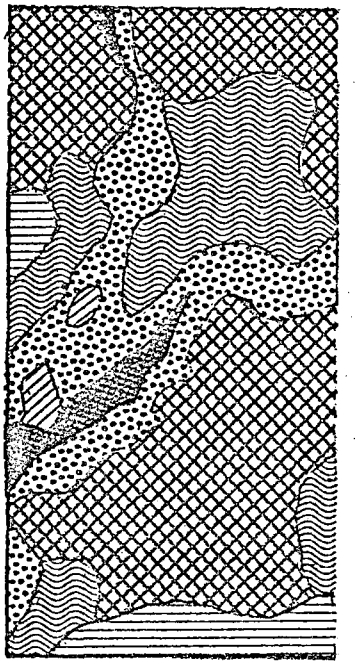
.5 0 1 Km.

N

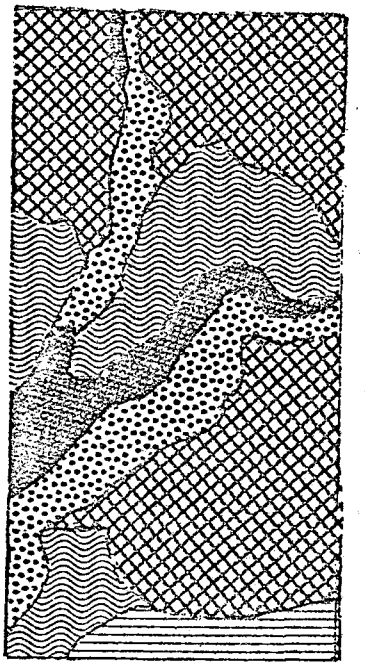
Base Map: U.S.G.S. 7½′ Quad



1 Ha. Grid



4 Ha Grid



11.1 Ha Grid

COVER TYPES

- Barren
- Grass
- chaparral
- Mixed Soft
- Mixed Hard
- Scrub Oak
- Mixed Oak Woodland
- Mixed Pine Woodland
- forest
- Mixed Deciduous
- Mixed Coniferous
- Oak

very desirable to determine if such a data base could provide the basic information, or at least the vegetative cover information, required by the FBIIS' remote site inventory. As shown below, the results were very disappointing; the ERTS data simply did not meet earlier claims (Nichols 1974).

Procedures. The research plan was to reconstruct the site inventory for the 6 sq km area (used to test the four FBIIS resolution levels) from ERTS data tapes and compare the results to the original FBIIS inventories.

This was not possible due to inadequacies in the ERTS tapes. After many man-weeks of wasted work, and considerable computer time, we learned that it is not currently possible to even locate specified areas on the ERTS data tapes, due to problems with the data and/or the tapes and/or the transformation programs. Attempts to locate the appropriate data manually, from voluminous printouts, also proved unsuccessful.

Finally, from the preliminary ERTS study (Nichols 1974), we located a printout which could manually be located on the 7½' topographic maps of the Santa Monica Mountains (well outside our study area). Thus we could develop the FBIIS site inventory for this area from the U-2 photos and related materials.

First we conducted detailed comparisons of the ERTS and U-2 vegetative cover types to develop a correspondence table. Then we constructed vegetative cover overlay maps for a 9 sq km area from:

1) 4 ha resolution FBIIS (U-2 photos);
2) 11.1 ha resolution FBIIS (U-2 photos); and
3) best (raw, not reconstructed) ERTS data available.

Results. The comparative maps from the 4 ha FBIIS and ERTS appear in Figure 8. Several results require discussion here.

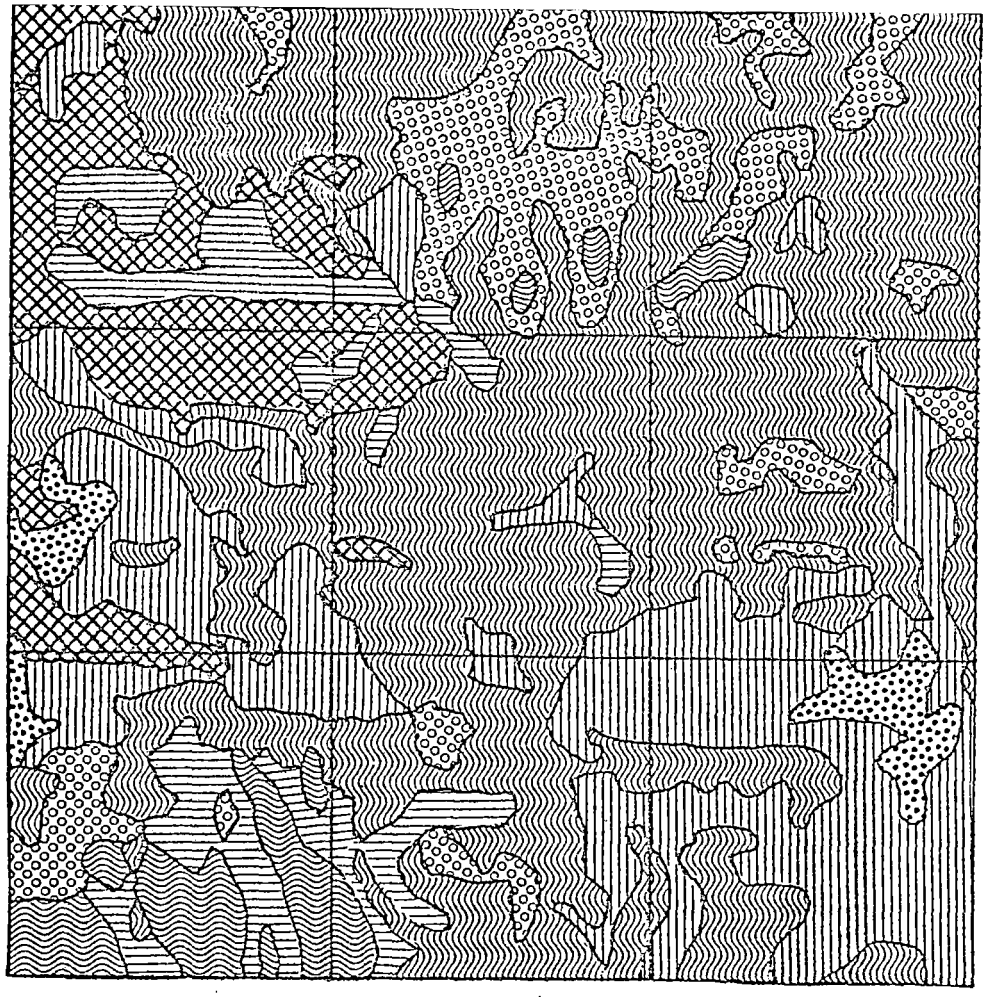
Much of the practical distinction among the 30 ERTS cover types (Nichols 1974) is illusory. For example, several "urban", "grassland" and "brush" types offer no real distinction for fire or land management purposes -- imagery differences do not necessarily translate to practical land differences. Thus, for this 9 sq km area, only eight basic types -- not 30 -- were present.

The well under 1 ha resolution of a single pixel is also misleading. Generally, single pixel (sometimes even several pixels) departures from the surrounding cover type(s) did not correspond to any observable features. (Often they were just plain incorrect, such as non-existant trees in grassland). Thus, the resulting "resolution" (but not the accuracy) from ERTS was similar to the 4 ha FBIIS, and was by no means near the 60 - 80 m earlier claimed.

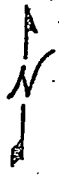
In addition, a rotation error of approximately 10 degrees was observed with the ERTS data. Thus, for each 1000 m of travel from the initial reference point, stands are displaced 180 m in counter-clockwise rotation.

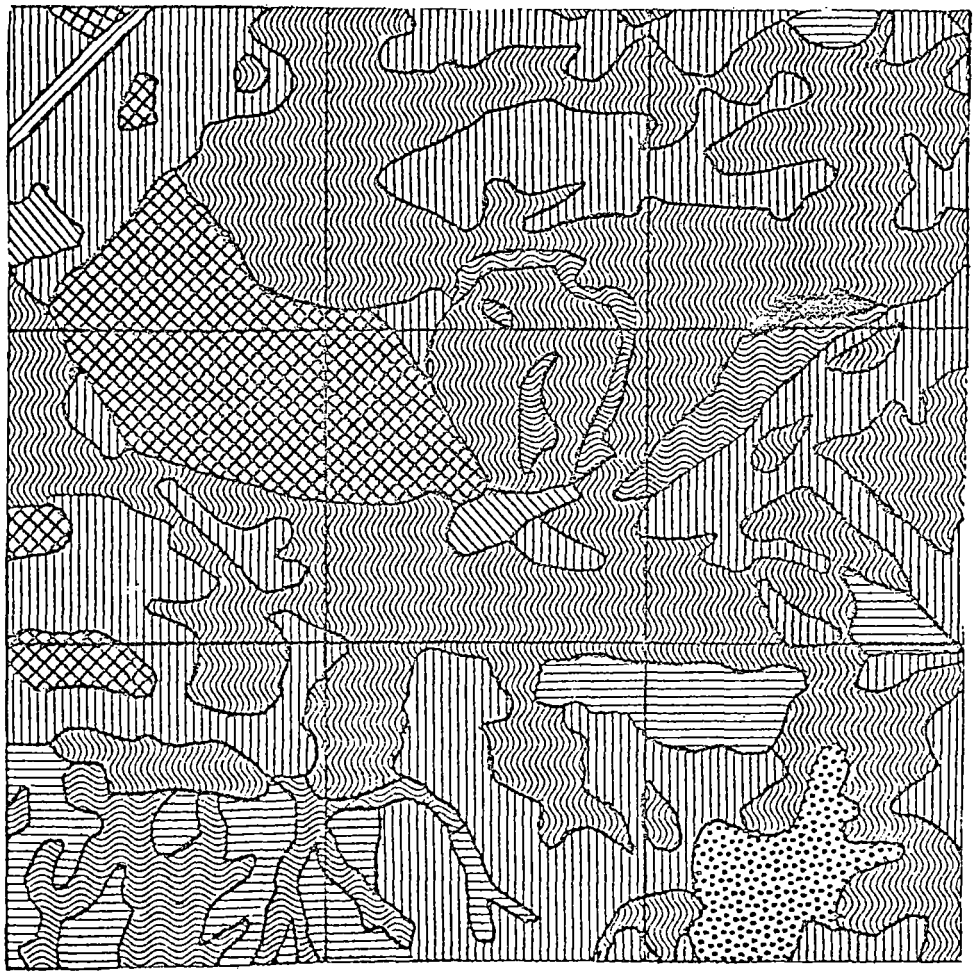
Finally, and of greatest importance, the point by point correspondence of the ERTS interpretations to the FBIIS was only 54 % within the 9 sq km area -- nearly half of the area was incorrectly classified.

Figure 8. Comparison of vegetative cover information from the 4 ha grid FBIIS and the ERTS-LANDSAT digital tapes for a 9 sq km area in the Santa Monica Mountains. Correspondence of the ERTS data to the FBIIS is only 54 %; in addition, the ERTS data is subject to a 10 degree rotation error.



ERTS





4 ha.
GRID

Obvious examples of this misclassification may be seen in Figure 8. The large cultivated area centered in the NE corner of sq km 3786 N, 317 E has no brush, but much of it is classified as brush by ERTS. The barren fireline running through 3787 N, 317 E is not recorded by ERTS. ERTS also classified portions of the chaparral and grassland in 3785 - 3786 N, 317 E as urban.

Much of the soft chaparral-grassland area in the north portion of this 9 sq km area is correctly classified by ERTS, and ERTS has the advantage of recognizing a soft chaparral - grassland mix (FBIIS does not). However, ERTS lost most of the hard chaparral in 3786 N, 318-319 E, and ERTS lost all of the forest enclaves in this area. ERTS also misplaced most of the oaks in the hard chaparral area dominating the SW corner of the 9 sq km area. Careful comparison of the maps in Figure 8 will show many additional problem areas, while the rotation error is most visible with the displacement of the urban area in 3785 N, 319 E.

Thus our testing of ERTS gives results which widely depart from the claims of Nichols (1974), and leave the basic question still generally unanswered. ERTS may, once the many, many bugs are removed from the current system, have some value to FIRESCOPE managers, but our results suggest that the system's capabilities are much more limited than earlier suspected. At the present time, it does not offer a viable alternative to the FBIIS' remote site inventory coded from U-2 photos, maps and fire records; even if it could provide adequate cover data, other required data (stand age, steepness, cultural data) must come from other sources.

CONCLUSIONS

The development of the FBIIS as reported here demonstrates that the techniques of gradient modeling may be used to link a site inventory, fuel models and appropriate software to meet the data base, retrieval and inference requirements of FIRESCOPE as detailed in the cooperative agreement and Study Plan. Many different resolution levels are available, with corresponding differences in data resolution, quality and costs.

Any system adopted for a large area should undoubtedly handle several resolution levels, such that low resolution, inexpensive site inventory may be coded for remote or other non-critical areas, while still providing high resolution where it is deemed necessary. At the present time, ERTS does not offer a reasonable data base alternative. ERTS can provide resolution, but not accuracy, comparable to the 4 or 11.1 ha FBIIS, and accuracy comparable to the 100 ha FBIIS, but only with greater manpower and computer costs (ERTS does not provide the stand age data required to infer fuels, and thus much manual work is required even if ERTS generates the vegetative cover).

Several questions must be addressed before a decision is made to implement such a system for the FIRESCOPE area:

1) how does the current output resolution translate as fire behavior - control resolution ?

2) how much site-specific and summary resolution and accuracy is required for different management areas ?

3) what other uses, such as refined vegetative community and dynamics data retrieval and inference, may be required by uses of the system other than fire control (vegetation management, land use planning, etc.) ?

4) what are the short- and long-term fire and land management alternatives if such a system as the FBIIS is not implemented for the FIRESCOPE area ?

When such questions are at least partially answered by management, then intelligent decisions can be made to develop and implement a system offering greatest utility for the lowest possible cost.

ADDITIONAL MATERIALS INCLUDED WITH THE OFFICIAL COPY OF THE FINAL REPORT:

1. Documented listing of the FBIIS source program, FORTRAN IV of HP-2000 System ("FBIIS, Version 11, 770228"), stored as file "SGMI1".

2. MEMOREX Tape 964383130, containing a single 80 character logical record data file. File includes current fuel models (first 45 lines), program dictionary (next 47 lines), and 140 sq km site inventory (next 14,140 lines).

3. Listing of above file.

4. PRIMUS Tape AD12362125010 containing five files: SGMI1, SGMI2, SGMI3, SGMI4 and SGMI5.

SGMI1 is a back-up copy of the FBIIS, Version 11, 770228 FORTRAN IV source program.

SGMI2 is the 4 ha block summary mode only version of the FBIIS used to test the 4 ha block site inventory.

SGMI3 is the 11.1 ha block summary mode only version of the FBIIS used to test the 11.1 ha block site inventory.

SGMI4 is a data file containing fuel models (45 lines), dictionary (47 lines) and 4 ha block site inventory for 6 sq km.

SGMI5 is a data file containing fuel models (45 lines), dictionary (47 lines) and 11.1 ha block site inventory for 6 sq km.

5. Listings of data files SGMI4 and SGMI5 described above.

6. Original coding forms and 14,140 punched cards for the 140 sq km study area (8 boxes of cards).

7. 7½' topographic maps showing the location of the 140 sq km study area.

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APPENDIX 1

SAMPLE OUTPUT FROM THE FIRE BEHAVIOR INFORMATION INTEGRATION SYSTEM

```
:PR,RGMI
1

 WELCOME TO THE PROTOTYPE FBIIS (FIRE BEHAVIOR INFORMATION INTEGRATION SYSTEM)
   BEING DEVELOPED FOR PART OF THE  FIRESCOPE AREA.

 MODEL DESIGNED BY GRADIENT MODELING, INC., FOR THE USDA FOREST SERVICE.
   SOURCE PROGRAM BY S R KESSELL AND M W POTTER, GRADIENT MODELING, INC.


   ENTER A 6-DIGIT DATE -- YEAR (2 DIGITS), THEN MONTH (2 DIGITS)
     THEN DAY (2 DIGITS).  DO NOT IMBED BLANKS.
770202


 PLEASE SELECT OPERATION MODE.
   YOU MAY CHOOSE INDIVIDUAL  HECTARE MODE (H) OR STATISTICAL SUMMARY MODE (S).
   TYPE BYE TO TERMINATE SESSION.
   NOW ENTER H, S OR BYE.
S

 STATISTICAL SUMMARY MODE SELECTED.


 YOU MAY NOW CHOOSE THE OPTIONS DESIRED.
   THESE INCLUDE: TERRAIN-SITE (T), VEGETATIVE COVER (V), FUEL LOADING AND
   PACKING (F), CULTURAL FEATURES (C), HYDROLOGICAL FEATURES (H)
   FIREBREAKS (B), AND ALL OPTIONS (A).

 NOW ENTER FROM ONE TO FIVE LETTERS IN A SINGLE STRING TO SPECIFY YOUR OPTIONS.
A


 NOW SELECT THE SQUARE KILOMETERS YOU WISH INCLUDED IN SUMMARY.
 ENTER A STRING OF 7 DIGITS - THE FIRST 4 ARE UTM NORTH,THE NEXT 3 ARE UTM EAST.
 HIT RETURN AND REPEAT FOR EACH LOCATION DESIRED.
 ENTER -1 WHEN SELECTION IS COMPLETED.
3779431
3779432
3780431
3780432
```

Kessell
FBIS
770202
Area 1

Summary mode

STATISTICAL SUMMARY ANALYSIS FOR THE 400 HECTARE AREA
INCLUDED IN THE FOLLOWING SQUARE KILOMETERS:

3779 NORTH, 431 EAST
3779 NORTH, 432 EAST
3780 NORTH, 431 EAST
3780 NORTH, 432 EAST

SITE - TERRAIN

ELEVATION (FEET)	PERCENT	HECTARES
0000 - 0500	.0	0
0500 - 1000	.0	0
1000 - 1500	.0	0
1500 - 2000	15.7	63
2000 - 2500	43.0	172
2500 - 3000	15.0	60
3000 - 3500	23.2	93
3500 - 4000	3.0	12

TOPOGRAPHY	PERCENT	HECTARES
URBAN	.0	0
LAKE,POND OR RESERVOIR	.5	2
FLAT	3.8	15
CANYON	.0	0
DRAW	19.8	79
SLOPE	59.1	236
RIDGE-PEAK	16.8	67

ASPECT	PERCENT	HECTARES
NORTH	3.7	15
NORTHEAST	5.7	23
EAST	3.7	15
SOUTHEAST	22.7	91
SOUTH	20.0	80
SOUTHWEST	30.0	120
WEST	4.7	19

AVERAGE SLOPE STEEPNESS = 30 - 45 PERCENT

VEGETATIVE COVER

MAJOR COMMUNITY TYPES	PERCENT	HECTARES
BARREN	.4	1.0
GRASS	4.9	19.5
SOFT CHAPARRAL	0.0	20.0
HARD CHAPARRAL	79.5	318.2
FOREST ENCLAVE OR EMERGENT	5.5	22.2
FOREST	2.5	9.9
DESERT	.0	.0
REMAINDER ~~LAKE~~ OR URBAN	.5	2.0

REFINED COMMUNITY TYPES

HARD CHAPARRAL COVERS 79.5 PERCENT= 318.2 HECTARES

BREAKDOWN INCLUDES:

	PERCENT	HECTARES
MIXED HARD CHAPARRAL	51.9	165.3
SCRUB OR WOODLAND OAK + CHAPARRAL	48.1	152.9
NON-CONTIGUOUS DESERT CHAPARRAL	.0	.0
CHAMISE	.0	.0

FOREST ENCLAVE OR EMERGENT COVERS 5.5 PERCENT= 22.2 HECTARES

BREAKDOWN INCLUDES:

	PERCENT	HECTARES
OAK ENCLAVE	95.9	21.3
DOUGLAS-FIR ENCLAVE	2.7	.6
PINE EMERGENTS	1.4	.3

FOREST COVERS 2.5 PERCENT= 9.9 HECTARES

BREAKDOWN INCLUDES:

	PERCENT	HECTARES
BROADLEAF FOREST	86.9	8.6
OAK WOODLAND	.0	.0
CONTINUOUS PINYON - JUNIPER	.0	.0
NON-CONTINUOUS PINYON - JUNIPER	.0	.0
RIVERINE COMPLEX	.0	.0
CONIFEROUS FOREST	13.1	1.3
PINE FOREST	.0	.0

FIRE HISTORY (AGE)	PERCENT	HECTARES.
00 - 10	.0	0
10 - 20	81.2	325
20 - 30	.0	0
30 - 40	.0	0
40 - 50	.0	0
OVER 50	18.2	73
REMAINDER - LAKE OR URBAN	.5	2

FUEL

LOADINGS (TONS/HA)	MEAN	SAMPLE DEVIATION	05 % RANGE	95 % RANGE
BRANCHWOOD(0 - .125 IN)	3.02	1.07	2.03 - 4.00	.91 - 5.12
BRANCHWOOD(.125 - .25 IN)	9.34	3.39	0.24 - 12.45	2.69 - 15.99
BRANCHWOOD(.25 - 1.0 IN)	19.21	7.17	12.05 - 25.77	5.15 - 33.27
BRANCHWOOD(1.0 - 3.0 IN)	1.85	.07	1.24 - 2.40	.54 - 3.16
BRANCHWOOD(OVER 3.0 IN)	.33	1.51	.00 - 1.70	.00 - 3.28
SHRUB FOLIAGE	10.23	3.79	6.70 - 13.09	2.80 - 17.05
GRASS AND FORBS	.07	1.00	.00 - 1.05	.00 - 2.70

PACKING RATIOS

SHRUB STRATUM	.0028	.0000	.0022 - .0033	.0010 - .0039
GRASS + FORBS STRATUM	.0048	.0007	.0042 - .0055	.0035 - .0062

CULTURAL FEATURES

SUMMARY BY SQ KM

KM	TOTAL NUMBER BUILDINGS	HIGH ORDER ACCESS BY QUARTERS
3779 431	15	NE: DIRT ROAD SE: DIRT ROAD SW: PAVED ROAD, 2 LANES NW: DIRT ROAD
3779 432	0	NE: DIRT ROAD

NW: DIRT ROAD

3780 43 1

NE: DIRT RO
SE:
SW: DIRT ROAD
NW: DIRT ROAD

3780 432 0

NE: DIRT ROAD
SE:
SW:
NW: DIRT ROAD

FIREBREAKS

LOCATION OF NATURAL AND ARTIFICIAL FIREBREAKS

KM	HECTARE		TYPE
3779	431	2 0	N
3779	431	3 3	A
3779	431	3 9	A
3779	431	4 4	A
3779	431	4 9	A
3779	431	5 4	A
3779	431	5 8	A
3779	431	0 5	A
3779	431	0 0	A
3779	431	0 7	A
3779	ed1	7 0	A
3779	431	8 5	A
3779	431	9 5	A
3779	432	0 1	A
3779	432	1 2	A
3779	432	1 3	A
3779	432	2 3	A
3779	432	2 4	A
3779	432	3 5	A
3779	432	4 0	A
3779	432	4 7	A
3779	432	5 7	A
3779	432	5 8	A
3779	432	5 9	A
3780	431	0 5	A
3780	431	1 4	A
3780	431	2 4	A
3780	431	3 4	A
3780	431	4 4	A

3780 431	6	1	A
3780 431	6	2	A
3780 431	6	7	A
3780 431	6	8	A
3780 431	6	9	A
3780 431	7	3	A
3780 431	7	4	A
3780 431	7	5	A
3780 431	7	6	A
3780 432	7	0	A
3780 432	7	1	A
3780 432	7	2	A
3780 432	7	7	A
3780 432	7	8	A
3780 432	8	3	A
3780 432	8	4	A
3780 432	8	5	A
3780 432	8	6	A
3780 432	8	9	A

HYDROLOGICAL FEATURES

SUMMARY BY SQ KM

KM	TOTAL PERCENT COVER BY WATER	TOTAL NUMBER SMALL WATER SOURCES	HIGH ORDER STREAMS BY QUARTERS NE	SE	NW	SW
3779 431	2	2	0	0	0	0
3779 432	0	2	0	0	0	0
3780 431	0	1	0	0	0	0
3780 432	0	2	0	0	0	0

END OF OUTPUT FOR STATISTICAL ANALYSIS.

PROGRAM WILL RETURN YOU TO MODE OF CHOICE.

PLEASE SELECT OPERATION MODE.
YOU MAY CHOOSE INDIVIDUAL HECTARE MODE (H) OR STATISTICAL SUMMARY MODE (S).
TYPE BYE TO TERMINATE SESSION.
NOW ENTER H, S OR BYE.

H

INDIVIDUAL HECTARE MODE SELECTED.

YOU MAY) CHOOSE THE OPTIONS DESIRED.
THESE CLUDE: TERRAIN-SITE (T), VEGETATIVE CO)(V), FUEL LOADING AND
PACKING (F), CULTURAL FEATURES (C), HYDROLOGICAL FEATURES (H)
FIREBREAKS (B), AND ALL OPTIONS (A).

NOW ENTER FROM ONE TO FIVE LETTERS IN A SINGLE STRING TO SPECIFY YOUR OPTIONS.
A

Hectare mode

NOW SELECT THE SQUARE KILOMETER DESIRED FOR DATA RETRIEVAL AND INTEGRATION.
ENTER A STRING OF 7 DIGITS -- THE FIRST FOUR ARE UTM NORTH,
THE NEXT THREE ARE UTM EAST. DO NOT IMBED BLANKS.
ENTER -1 TO RETURN TO MODE SELECTION.
3779432

PROGRAM WILL NOW TRY TO LOCATE THE SITE INVENTORY FOR THE SQUARE KILOMETER
LOCATED AT UTM 3779 NORTH, 432 EAST.

SITE DATA LOCATED.

NOW ENTER 2-DIGIT COORDINATES FOR THE INDIVIDUAL HECTARE, NORTH AND THEN EAST.
DO NOT IMBED BLANKS.
TO SELECT ANOTHER SQ KM, ENTER -1
01

ANALYSIS FOR HECTARE 1 IN SQ KM 3779 NORTH, 432 EAST-----
SITE-TERRAIN: ELEVATION= 1920 FEET, PRIMARY TOPOG= RIDGE-PEAK
SECONDARY TOPOG= SLOPE
ASPECT= NORTHWEST AVERAGE SLOPE= 15 - 30 PERCENT
VEG COVER: PRIMARY COVER= HARD CHAPARRAL
FURTHER DEFINED AS SCRUB OR WOODLAND OAK + CHAPARRAL
SECONDARY COVER= FOREST ENCLAVE OR EMERGENT
FURTHER DEFINED AS OAK ENCLAVE
STAND IS MATURE

```
      BRANCHWOOD .125 - .25 IN          11.52
      BRANCHWOOD .25 - 1.0 IN           31.70
      BRANCHWOOD 1.0 - 3.0 IN            3.00
      BRANCHWOOD OVER 3.0 IN              .90
      SHRUB FOLIAGE                     12.03
      GRASS + FORBS                       .20
          SHRUB STRATUM PACKING RATIO =  .0030
          GRASS + FORBS STRATUM PACKING RATIO =  .0050
NO HYDROLOGICAL FEATURES RECORDED
CULTURAL:
          ACCESS TO HA IS BY DIRT ROAD
          HA HAS FIREBREAK APPROX. 20 M WIDE
          ORIENTATION OF FIREBREAK IS NORTHEAST  - SOUTHWEST




NOW ENTER 2-DIGIT COORDINATES FOR THE INDIVIDUAL HECTARE, NORTH AND THEN EAST.
  DO NOT IMBED BLANKS.
TO SELECT ANOTHER SQ KM, ENTER -1
of




ANALYSIS FOR HECTARE 64 IN SQ KM 3779 NORTH, 432 EAST-----
  SITE-TERRAIN: ELEVATION=  2040 FEET, PRIMARY TOPOG= SLOPE
                    SECONDARY TOPOG= DRAW
                ASPECT= SOUTHEAST     AVERAGE SLOPE=  15 -  30 PERCENT
  VEG COVER: PRIMARY COVER= HARD CHAPARRAL
             FURTHER DEFINED AS MIXED HARD CHAPARRAL
             SECONDARY COVER= HARD CHAPARRAL
             FURTHER DEFINED AS SCRUB OR WOODLAND OAK + CHAPARRAL
             STAND IS MATURE
             SITE IS NOT CULTIVATED
FUEL:        TYPE              LOADING(TONS/HA)
     BRANCHWOOD 0 - .125 IN            5.20
     BRANCHWOOD .125 - .25 IN         10.20
     BRANCHWOOD .25 - 1.0 IN          31.70
     BRANCHWOOD 1.0 - 3.0 IN           3.00
     BRANCHWOOD OVER 3.0 IN             .00
     SHRUB FOLIAGE                    17.70
     GRASS + FORBS                      .20
         SHRUB STRATUM PACKING RATIO =  .0030
```

```
NO CULTURAL FEATURES RECORDED .

NOW ENTER 2-DIGIT COORDINATES FOR THE INDIVIDUAL HECTARE, NORTH AND THEN EAST.
  DO NOT IMBVU BLANKS.
TO SELECT ANOTHER SQ KM, ENTER -1
10

ANALYSIS FOR HECTARE 10 IN SQ KM 3779 NORTH, 432 EAST-----
  SITE-TERRAIN: ELEVATION=  2000 FEET, PRIMARY TOPOG= SLOPE
                ASPECT= SOUTH          AVERAGE SLOPE=  15 -  30 PERCENT
  VEG COVER: PRIMARY COVER= HARD CHAPARRAL
             FURTHER DEFINED AS SCRUB OR WOODLAND OAK + CHAPARRAL
             STAND AGE=  17 YEARS
             LAST FIRE WAS HI INTENSITY, DESTROYED MOST OF TOP STRATUM
             SITE IS NOT CULTIVATED
FUEL:        TYPE                LOADING(TONS/HA)
     BRANCHWOOD 0 - .125 IN          3.10
     BRANCHWOOD .125 - .25 IN        9.70
     BRANCHWOOD .25 - 1.0 IN        19.00
     BRANCHWOOD 1.0 - 3.0 IN         1.80
     BRANCHWOOD OVER 3.0 IN           .00
     SHRUB FOLIAGE                  10.00
     GRASS + FORBS                    .45
         SHRUB STRATUM PACKING RATIO =  .0030
         GRASS + FORBS STRATUM PACKING RATIO =  .0050
NO HYDROLOGICAL FEATURES RECORDED
NO CULTURAL FEATURES RECORDED

NOW ENTER 2-DIGIT COORDINATES FOR THE INDIVIDUAL HECTARE, NORTH AND THEN EAST.
  DO NOT IMBED BLANKS.
TO SELECT ANOTHER SQ KM, ENTER -1
```

```
ANALYSIS FOR HECTARE 58 20 SQ KM 3779 NORTH, 432 EAST-----
  SITE-TERRAIN: ELEVATION=  2280 FEET, PRIMARY TOPOG= RIDGE-PEAK
                SECONDARY TOPOG= SLOPE
                ASPECT= SOUTH          AVERAGE SLOPE=  15 -  30 PERCENT
  VEG COVER: PRIMARY COVER= HARD CHAPARRAL
             FURTHER DEFINED AS MIXED HARD CHAPARRAL
             SECONDARY COVER= HARD CHAPARRAL
             FURTHER DEFINED AS SCRUB OR WOODLAND OAK + CHAPARRAL
             STAND IS MATURE
             SITE IS NOT CULTIVATED
FUEL:        TYPE                LOADING(TONS/HA)
     BRANCHWOOD 0 - .125 IN          5.20
     BRANCHWOOD .125 - .25 IN       10.20
     BRANCHWOOD .25 - 1.0 IN        31.70
     BRANCHWOOD 1.0 - 3.0 IN         3.00
     BRANCHWOOD OVER 3.0 IN           .00
     SHRUB FOLIAGE                  17.70
     GRASS + FORBS                    .20
        SHRUB STRATUM PACKING RATIO =  .0030
        GRASS + FORBS STRATUM PACKING RATIO =  .0050
NO HYDROLOGICAL FEATURES RECORDED
CULTURAL:
          ACCESS TO HA IS BY DIRT ROAD
          HA HAS FIREBREAK APPROX. 20 M WIDE
          ORIENTATION OF FIREBREAK IS EAST      - WEST



NOW ENTER 2-DIGIT COORDINATES FOR THE INDIVIDUAL HECTARE, NORTH AND THEN EAST.
  DO NOT IMBED BLANKS.
TO SELECT ANOTHER SQ KM, ENTER -1
-1



NOW SELECT THE SQUARE KILOMETER DESIRED FOR DATA RETRIEVAL AND INTEG#A%ION.
  ENTER A STRING OF 7 DIGITS -- THE FIRST FOUR ARE UTM NORTH,
  THE NEXT THREE ARE UTM EAST.  DO NOT IMBED BLANKS.
  ENTER -1 TO RETURN TO MODE SELECTION.
-1
```

A-17

```
 PLEASE SELECT OPERATION MODE:
   YOU CHOOSE INDIVIDUAL HECTARE MODE (H) OR STATISTICAL SUMMARY MODE (S).
   TYPE BYE TO TERMINATE SESSION.
   NOW ENTER H, S OR BYE.
BYE



        BYE
  RGM11 : STOP    0000

@
```